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ABSTRACT

One area explored in the second (in-depth) phase of the Learning in Science Project was "children's science," defined as views of the world and the meanings for words that children have and bring with them to science lessons. The investigation reported focuses on students' thinking regarding their views on gravity. Students (N=42) were individually interviewed using a variation of the interview-about-instances procedure. Eight cards (included in an appendix), each illustrating a single situation where gravity may or may not occur, were shown to students to elicit their views. Data are presented and discussed under the following headings: gravity and force; gravity and weight; gravity and reaction forces; gravity and buoyancy; gravity and height; gravity and air; and gravity and space. Additional views presented and discussed focus on gravity as it relates to: children's everyday language; self-centered and human-centered viewpoints; animistic views; and reified views. Findings indicate that students believe that: weight and force of gravity are different; reaction forces and buoyancy forces are aspects of gravity; gravity varies with height in a way different from the scientific view; gravity results from the presence of air pushing down; gravity doesn't exist in space (including the moon); and gravity is caused by the earth spinning. (JN)

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LEARNING IN SCIENCE PROJECT

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GRAVITY

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WORKING PAPER No. 20

In our view successful science teaching requires an appreciation not only of the scientists' view of the world, but also an appreciation of the language, the beliefs and the expectations which children bring with them to science classes. This working paper has developed from a study carried out in the in-depth phase of the Learning in Science Project and is one of a series of papers which explores aspects of Children's Science (see Working Paper No. 14). It is our hope that these papers portray children's views of the world and meanings for words in a way which will be useful to teachers and to curriculum developers.

In the action-research phase of the project it is our intention to attempt to build practical and useful teaching strategies based on the findings of the in-depth phase of the project. For this reason we are actively seeking comments on the findings we have detailed, and seeking information on the variety of ways teachers develop ideas associated with the topic under focus in this paper.

We would be grateful if comment and/or information could be forwarded to

The Learning in Science Project,
University of Waikato,
Private Bag,
HAMILTON.

GRAVITY

A working paper of the Learning in Science Project

Keith Stead and Roger Osborne

November 1980

INTRODUCTION

> "You throw a ball up, you know, it will come down - it has to 'cos of the law of gravity. (What is this law?) What goes up must come down." (F4, boy)

One of the topics we have studied in depth as part of the Learning in Science Project is the topic of FORCE (Working Paper No. 16). That work made clear to us that certain ideas closely associated with the idea of FORCE should also be investigated, namely FRICTION[1] and GRAVITY[2].

The information detailed in this paper was obtained using a variation of the interview-about-instances method used to investigate FORCE. A deck of 8 cards (see Appendix 1) was used in individual interviews to provide a focus to discussion about the meaning held by students for the word GRAVITY. Each card depicted a single situation where gravity may, or may not, occur. Unlike previous studies the opening questions[3] were usually of the form "I'm interested in your meaning of the word GRAVITY; what can you tell me about it? What is it?" The interviewer then proceeded to discuss the stimulus cards using informal questioning. e.g. "Does that card illustrate gravity in any way? Tell me about it."

A total of 42 students ranging from Form 1 to Form 7 (7 x F1, 8 x F2, 12 x F3, 11 x F4, 4 x F5) from 6 different schools, as well as 3 Teachers College students (3 x T), were interviewed. Each interview session was audio taped and the consequent transcription carefully scrutinised to provide the data for this paper.

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[1] FRICTION is the subject of Working Paper No. 19.

[2] GRAVITY is not a term clearly defined in Physics. However in common usage it is short for "force of gravity" or "force of gravity per unit mass" (gravitational field). Considered from this point of view, the term GRAVITY does have a much clearer meaning in physics than say ELECTRICITY which is a term used for a wide variety of different concepts (e.g. electric field, electrostatic force, electric current, electric charge).

[3] After endeavouring to establish an informal, relaxed atmosphere and explaining the general nature of inquiry to the student.

In this paper responses to the initial questions, and subsequent discussion focussing on the cards, are summarised. In the first section of the paper various aspects of students' views are considered. The subsequent section deals with those aspects of children's views about GRAVITY which can be related to common findings from earlier investigations, e.g. Working Papers No. 16 on FORCE, No. 19 on FRICTION).

Following the interview work and the analysis of the results a small survey was developed to investigate the prevalence of some of the views of gravity already identified. In developing the survey questions, further interviews explored the reasons why children chose particular responses and this led to modification of the questions so that the prevalence of those particular views we were interested in could be ascertained. The further information produced by this survey is referred to where appropriate in the body of the paper.[4]

ASPECTS OF STUDENTS' VIEWS ON GRAVITY

(a) Gravity and force

When explicitly asked "what is gravity? Tell me about it", 9 students were unable to give any clear statement (3 x F2, 3 x F3, 3 x F4). Almost all other students implied or stated it was something that "holds" (4 x F1, 2 x F2, 6 x F3, 7 x F4, 1 x F5), "pulls" (2 x F1, 2 x F2, 2 x F3, 1 x F4, 1 x F5, 2 x T) or "pushes" (1 x F3, 1 x F5, 1 x T). Of these, 9 students (1 x F2, 1 x F3, 2 x F4, 2 x F5, 3 x T) explicitly stated that it was a force;

> "It's a force that holds us down." (F3, boy)

> "It's a force exerted by bodies and the further the distance, the less the force ... all objects have it and the bigger they are, the more gravity they have." (F5, boy)

The most common answer related to holding or pulling, people or objects, down to the ground. For example,

> "It holds you down." (F2, girl; also 3 x F1, 1 x F2, 4 x F3, 4 x F4)

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[4] The survey results were obtained from children covering a full range of abilities in co-ed and single-sex schools (7 schools); Form 3-5 students were studying science and Form 6-7 students were studying Physics.

"It pulls us down." (F1, girl; also 1 x F1, 2 x F3, 1 x F5, 2 x T)

In the course of further discussion this pull was sometimes compared to a magnetic force. For example,

"It's like one of those magnets when it attaches (to) something like the earth, and it attaches people to it and objects all over it." (F2, boy)

This analogy is not surprising in that magnetic attraction is probably the only non-contact pulling force apart from gravity that most students are familiar with. Sometimes however, students considered it to be a magnetic force repelling from above.

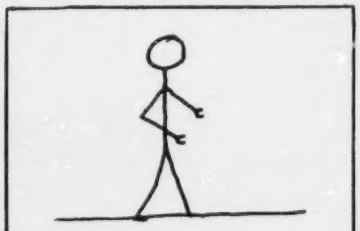
"It is a force that's something in the atmosphere that stops you floating around in it. Sort of magnetic force which keeps you steady and firm on the ground and that without it you wouldn't be able to walk around." (F3, girl)

Those that viewed gravity as a push, rather than a pull, also viewed gravity as acting downwards from above.[5] For example,

"It's pushing down on the earth to keep things down so they won't fly around." (F3, boy)

"It's a force that's going down to earth - pushing down to earth - it applies to all objects - pushes them down." (T, girl)

In summary, the majority of students interviewed had a view of gravity as something that "holds", "pushes" or "pulls", and in that sense was viewed by students as a force.[6] Most students tended to consider gravity first and foremost as something that affects us here on the surface of the earth. The following survey question investigated what proportion of students considered gravity to be present at the earth's surface.



I Standing on the earth

Look at picture I. Is there any <u>gravity</u> when you are standing on the earth.

(a) Yes
(b) No

Results as percentages: (concensus physics view underlined)

	3rd (N = 257)	4th (N = 202)	5th (N = 179)	6th (N = 146)	7th (N = 75)
a	94	96	98	99	100
b	6	4	2	1	-

[5] This will be reconsidered later in section 2(f).

[6] In terms of a scientist's meaning of the word force

(b) Gravity and weight

The word "gravity" is ambiguous from a scientific point of view in that it can relate to the pull of gravity on an object, which is the scientific meaning for the word weight, or it can mean the pull of gravity per kilogram, which is the scientific meaning for gravitational field. This distinction was not really made by anyone who was interviewed; however, students could be identified at all ages who had the idea that there was a close relationship between gravity and weight. For example, a Form 1 student on being asked if a large person is affected by gravity more than a small person stated,

> "Well, he'd be heavier ... he'd go down faster (on a see-saw) because there's more of him that gravity can grab on and pull him down." (F1, boy)

Also,

> "(gravity) weighs the boy down." (F2, boy)

> "(How does weight tie in with gravity, David?) Well, the heavier the object is, the more pull the gravity will give." (F4, boy)

> "The heavier the object, the more force has to be applied to push the object down." (T, girl)

On the other hand students could be found who did not associate gravity and weight quite so closely. One card depicted a girl pulling up a bucket from a well using a pulley system (No. 6). The bucket is in mid-air and the student was asked to explain why the bucket drops as the rope is paid out:

> "It could be (due to) the rope but it all depends. (It all depends on what?) What you've got in the bucket. (Oh, I see, okay. Well, let's say we had nothing in the bucket, what would happen then?) Oh, the gravity would be pulling it down. (And if we put something in the bucket?) Weight would be pulling it down." (F2, girl)

Also, from older students,

> "Well, if one side (of a see-saw) got more gravity and the other side's got less weight, well, the gravity would weigh more." (F5, girl)

> "Gravity only affects heavy objects." (F5, boy)

> "I get mixed up when I start talking about weights pushing down and then gravity pushing down. I think there could be some connection - there is some connection." (T, girl)

One of the confusions between weight and gravity is that weight in common usage refers to the total pull on an object as measured on a balance. From this point of view it is possible for there to be gravity but to have no weight, e.g. in a satellite or when swimming underwater. What is in fact more surprising is that some younger students consider that you can have a weight without the presence of gravity. For example,

> "(Spacemen) have lead weights in their boots ... to keep them down ... 'cos there is no gravity on the moon." (F1, boy)

Examples of such a view had earlier been found in older students (1 x F3, 1 x F5, 2 x T) and are detailed in the Working Paper No. 16 on Force (p.11).

(c) Gravity and reaction forces

In our study of force we noted that to some students when an object is in free fall there is no force on it; "it just comes down naturally". Perhaps it is therefore not surprising to find some students who view gravity as more of an upwards reaction force. For example, in response to a query concerning a springboard diver before he plunges into the water:

> "(Would there be any gravity involved?) Oh, there would be some when he's jumping up and down otherwise he would fall over, but when he dives in there is not really 'cos he's falling straight down; it doesn't hold him up or anything." (F3, girl)

Similar responses occurred when explaining how birds are able to fly with respect to gravity:

> "Well, humans can't fly so birds have got something - they're naturally lighter - there must be some kind of gravity up there keeping them up there - um - movement, you know, flapping their wings is keeping them up there. (What happens when they don't flap their wings?) They're gliding. There must be gravity to keep them up to glide, but flapping's moving them. Like the gliding is too, so there must be gravity pushing them maybe. Probably when they're coming down, the gravity is against them." (F4, girl; also 1 x F2, 1 x F4)

A fifth former clearly showed this confusion between gravity and reaction forces:

> "(What tells you that there is gravity?) 'Cos I'm walking on it! (You're walking on gravity?) Yeah. (And if gravity wasn't there? What would happen to you?) Probably sink." (F5, girl)

An associated view was one that considered gravity a holding force; holding us vertical. Without gravity there would be no human verticality or posture; we would float around and not remain upright. An example of this view is,

> "It holds us up - gravity holds us up ... if we are standing up we don't fall down again, sort of straight away. You can fall down if you want to but you don't unless you trip over, but it holds you standing upright." (F3, girl)

(d) Gravity and buoyancy

Students did not have a clear understanding of buoyancy, perhaps because we no longer teach Archimedes' Principle as a matter of course in science lessons. It is therefore not surprising that there are a considerable variety of views about the presence or otherwise of gravity in water.

To some, there is no gravity in the water:

> "Well, there mustn't be gravity though, because you can make yourself float - you hold yourself up kind of thing in the water - kicking and that, so it mustn't be." (F3, girl)

> "I don't think there really is any 'cos the water is sort of holding him up, he's sort of floating in the water as you swim. (What happens if he was to swim underwater? There be any gravity?) I'm not sure. I don't think so 'cos he's holding himself under, he's making himself go under, you know." (F3, girl; also 1 x F1)

> "I don't think it's really got anything to do with it 'cos your body naturally floats on top of the water and so it can't be that it's balancing on top of the water 'cos your body naturally floats, and it's not making you sink and it's not making you rise, so I don't think it's got much to do with it." (F4, girl; also 1 x F4)

To others there is some gravity underwater, but it is less:

> "Gravity might still be there, but it's not very near strong enough to hold you down there ... but if you had a weight on, you'd stay there 'cos there's a weight." (F1, boy)

> "Yes, gravity - there is - it is a bit. Oh, water reduces the gravity. There is still gravity in the water but water must just decrease (it) - I don't know why -." (T, girl; also 1 x F3)

However, later this confusion was resolved by this student who decided that gravity acted only on the parts of the body above the water's surface:

> "(Let's take that chap there, he's now horizontal on the water ... if he was to tread water and stand vertically, what effect is that going to have on the gravity?) Well, most of his body would be in the water ... so there'd only be his head for gravity to push down on, so it'd be lighter." (T, girl)

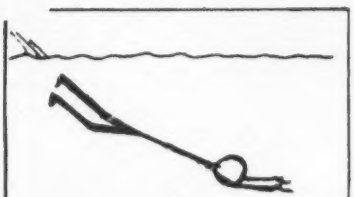
Others more consistently believed there was gravity in the water but it was upwards.[7]

> "There might be gravity going through all the water; that might be keeping you on top of the water." (F1, girl)

> "(The gravity's) not very strong but it helps him to swim better - buoyant. (And if he goes underwater? What happens to the gravity then? Is it still there?) Yeah, because when you're underwater and you stop swimming you go straight to the surface. There's a strong push from the bottom going upwards." (F3, boy; also 1 x F2, 1 x F5)

> "It must be different - the gravity changes - it must be above water because when you go down, if you just stay there, you come up ... (And this is gravity pulling you back up to the top?) Mmm, it's probably reversed, or something." (F4, boy)

The following survey question investigated how many students considered there was gravity underwater. Unfortunately, how many of these that gave answer (a) considered gravity to be upwards is unknown.



V Swimming underwater

Look at picture V. Is there any <u>gravity</u> when the person is swimming underwater?

(a) Yes
(b) No
(c) Depends on whether the person is going up or down.

Results as percentages:

	3rd (N = 256)	4th (N = 198)	5th (N = 179)	6th (N = 145)	7th (N = 75)
a	40	60	63	87	93
b	23	28	29	12	5
c	37	12	8	1	1

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[7] Some of these students did seem to appreciate that gravity would have to act downwards on the water at least at the bottom.

> "I think gravity's on the bottom, holding the water down." (F2, girl)

> "There's not a gap between the bottom of the water and the bottom of the sea." (F4, boy)

(e) Gravity and height

The idea of gravity underwater being less than above the water, is not inconsistent with the idea some students hold that gravity increases with height above the earth's surface.[8]

Consider the following extracts from a discussion with a 4th former.

> "What I've heard, the higher you go up, the stronger the gravity is, until you get out of the atmosphere."

and when responding to the card showing a rocket ship taking off (No. 8) he explained,

> "A space ship going quite fast 'cos of the pull - the higher it goes, the stronger the gravity is. Therefore, it is got to be able to go very fast and to go against the pull of gravity. Oh, it's got to climb quickly."

This student was able to provide an insightful analogy when explaining why the gravity is much stronger at the extremities of the atmosphere:

> "It's because it's ... sort of like a human actually trying to reach something and the desperate attempts are the strongest." (F4, boy)

To some, gravity was related to the movement of a body (card No. 7, slide).

> "(Is there any gravity involved there?) Yeah, to get him from the top to the bottom ... it's sort of helping him go down. (Is gravity the same at the top as it is at the bottom?) Oh, he'd be going faster you know when he got to the bottom, if that would make any difference to it." (F4, girl)

Similar views were expressed by older students:

> "It would be stronger at the top - the gravity would be pulling him down more but if he were at the bottom, it wouldn't move as fast you know. (So why is the gravity going to be stronger at the top of the slide?) Because it's got further to come. (And when he gets to the bottom he stands up - what's the gravity like then?) Oh, you know, it's just - it's normal." (F5, boy)

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[8] In terms of the scientific view of gravity, the pull of gravity is always downward, and both above and below the earth's surface, is less than at the earth's surface. Mathematically below the earth's surface, the pull of gravity is proportional to the distance from the earth's surface. Above the earth's surface the pull of gravity is inversely proportional to the square of the distance from the centre of the earth. This means that near the earth's surface the pull of gravity is practically constant with height - within 1% of the value at the earth's surface from 32 km above the earth's surface to 64 km below the earth's surface.

"It (the gravity) depends on the height. (In what way?) If it (the slide) was high, it would help them to move faster, and if it was low, it'll just move them slower. (I see, so the gravity is stronger up high?) Hmm." (F5, girl)

"Oh well, the force of gravity can be felt if you're higher up. I mean, if you jump down from something high up, you're obviously going to fall a lot heavier than if you jumped from something lower down. That's got to do with position. (So you're saying that the higher you are, the stronger the gravity?) Hmm." (T, girl)

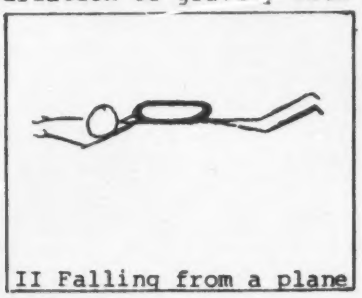
Three Form 1 and Form 2 children who had very little idea about gravity at all seemed to associate gravity with movement. Also unpublished work done at the Institute for Educational Technology, University of Surrey, suggests gravity may be associated in some children's minds with the act of falling. These ideas may be connected to the above ideas about gravity and height. Of course not all students considered gravity increased with height. However, not only were there those who considered it remained approximately constant, or even decreased with height, but there were also some (2 x F3, 2 x F4) who considered gravity was zero above the earth's surface. In response to the card depicted by a flying bird (Card No. 2) "Does the bird experience any gravity?" they replied:

"Probably not; it (the bird) can go up and stay there." (F4, girl; also 2 x F3)

"No, gravity is only near the earth." (F4, boy)

No doubt again these ideas are related to confusion about reaction forces, buoyancy and so on.

As an indicator as to the prevalence of particular views related to the variation of gravity with height the following survey question was used.



II Falling from a plane

Look at picture II. Is there any gravity?

(a) Yes, about the same as on the ground
(b) Yes, but much less than on the ground
(c) Yes, but much more than on the ground
(d) No, there is no gravity

Results as percentages:

	3rd (N = 257)	4th (N = 200)	5th (N = 179)	6th (N = 147)	7th (N = 74)
a	26	35	41	56	65
b	32	31	38	31	27
c	31	29	20	12	8
d	11	5	1	1	-

(f) Gravity and air

If one has the view that gravity increases with height then there must be some place where it decreases. This is because many students consider that there is no gravity in space.

> "Well there's the world and gravity - oh, the sky and everything. It goes up to a maximum place - it's got a maximum where it can stop." (F1, girl)

One student, had it all worked out in his mind:

> "It's just a force field surrounding the earth, sort of thing - sort of helping us down - if there's gravity, and there's that ozone layer, and it carries on, sort of thing. Atmosphere is for breathing and it carries on - it's just layers of different substances around the earth and one of these is gravity that holds us down and when we get up to the moon and that - and out in space, there's nothing there - there's no atmosphere or anything ... this planet's (earth) got an atmosphere, it's got a sort of shield, or a shield or something holding the atmosphere down and it causes gravity, and it's just that this planet's got it - let's go to the moon say, it hasn't got any atmosphere or anything, any sort of ...a barrier of some sort, of atmosphere, or gravity or something like that." (F3, girl)

> "I don't think it (gravity) will affect there as the picture shows 'cos it's (the rocket ship) still pretty well down by earth but when it goes through our ... atmosphere ... they don't need all the power ... they don't really have to use much energy to get there once they've broken through the atmosphere." (F4, girl)

Both these quotations imply gravity is something to do with the atmosphere. Others (3 x F2, 1 x F3, 3 x F4, 3 x F5) more directly related gravity to the atmosphere.

> "There's atmosphere at levels, isn't there? And out of our atmosphere, after it, as it goes higher, the atmosphere there's only gravity in that atmosphere and yet in space where there's - oh, I don't think there's atmosphere in space, is there? So there's no gravity; there has to be atmosphere to have gravity." (F3, girl)

One student considered that gravity was a sucking action of the air:

> "(If we took our heavy round ball up to the moon ... does the weight change at all?) No, it'll go light. 'Cos, you see, there'll be no air sucking into it and see, if air is sucking into it, it only gets heavy, but if I take way up on to the moon and I just hold it like that, it'll be going up and away in the ... atmosphere." (F2, boy)

Others considered gravity to be something in the air:

> "It's something in the air that keeps you down." (F1, girl)

"... the earth travels gravity out and that mixes up in the air and, you know, when you're breathing it - really the air is all over the place - it will be attached to the ground and so it will keep you on the earth. (So when I take a deep breath of air, I'm taking some gravity too?) Yeah, when it's mixed together." (F2, boy)

This idea was expressed in another way by a third form girl wrestling with an explanation of how a hovercraft rides on a cushion of air, seemingly defying the effects of gravity.

"The compressed air probably doesn't have as much gravity in it as free air, free-flowing air, and the pressure on it might have something to do with forcing the gravity out of it ... as the air is being compressed and the molecules might, could be forcing the molecules of gravity out into where it is not being compressed, into free-flowing air."

In another part of the interview, when being asked about the presence of atmosphere on the moon (and its perceived association with gravity), she responded,

"There is probably an atmosphere consisting of different ... chemicals and things in it like that, that causes less gravity."

This is obviously more sophisticated than the response of the Form 1 student but it does, nevertheless, show an adherence to a mechanistic concept of gravity.

It is perhaps not surprising that students associate gravity with the presence of air. Above the earth satellites orbit in a "weightless" environment.

"(Gravity) has no effect on him 'cos he's just weightless." (F5, boy)

The necessity of a force to keep a satellite in orbit is not appreciated - a man on a spacewalk is out of the atmosphere, out of the gravitational field and just floating free. The prevalence of this view was surveyed.

IV Spaceman near a satellite

Look at picture IV. The satellite is going around the earth. Is there any <u>gravity</u> up where the spaceman is?

(a) Yes
(b) No

Results as percentages:

	3rd (N = 253)	4th (N = 198)	5th (N = 178)	6th (N = 147)	7th (N = 75)
a	19	25	28	57	65
b	81	75	72	43	25

(g) Gravity and space

As might be expected from the last subsection, students could be found who held the belief that there was no gravity at all on the moon.

"It's only on earth as much as we know and it's not on the moon, or anywhere like that." (F1, boy; also 2 x F1)

"So if there's no air up on the moon, that means that there won't be much gravity." (F2, boy)

"Oh, there's gravity on other planets; there's probably gravity on nearly every planet in the galaxy, or universe. While not every planet does have gravity, like the moon." (F4, boy)

"Well, the moon's got no gravity and you float off - and out in space, you just float around." (F4, boy)

A survey question was used to investigate the prevalence of this view.

III Standing on the moon

Look at picture III. Is there any gravity?

(a) Yes, but much more than on the earth
(b) Yes, about the same as on the earth
(c) Yes, but much less than on the earth
(d) No, there is no gravity

Results as percentages:

	3rd (N = 258)	4th (N = 201)	5th (N = 179)	6th (N = 145)	7th (N = 75)
a	12	7	3	-	-
b	2	3	1	1	-
c	42	67	70	96	96
d	44	24	26	4	4

(h) Gravity and spinning

One of the most difficult viewpoints to understand was the association in some students' minds between the spinning of the earth and gravity.

"I'm not that far advanced in this but I know that this gravitational force holding us down is created by us spinning and the sun." (F3, boy)

"Gravity is caused by the rotation of the earth because as the earth moves around, it sort of makes a pull and that's why people, or we, don't fall off the earth. I think it's (gravity) weakening because the earth's slowing down in its rotations." (F4, boy)

"I believe gravity is a force which pulls everything to the centre of the earth. It gets less as you go out from earth. It's to do with the spin of the earth." (T, girl)

Initially these ideas seem very strange to anyone holding the scientific view, in that "intuitively" one might think that there would be a tendency for us to get thrown off a spinning earth. Other students comments, however, suggest some students have the idea that artificial gravity can be created by spinning and hence the earth's gravity is created in the same way.

"I think that if (the earth) didn't spin, there would be less gravity. Sort of like momentum ... (You think momentum perhaps might be involved in some way?) Yeah. (Why?) Well, it's just that certain things that happen ... I had a horse and I had a bucket I used to put feed in the bucket and if you're spinning it around, it'll stay in the bottom even when it's up in the air because of the momentum of the force that's keeping it up there ... it might be sort of the same as the earth's spinning - it might cause gravity." (F3, girl)

"I just think gravity is like when you have a ball in a bucket and you swing it around, the ball doesn't come out but it's because something's holding it there." (F4, girl)

The whole problem is clarified very nicely by a Form 3 girl,

"When you swing a bucket over your head, you've got the gravity holds it in, at least that's what I've been told. And I don't know why. I think it's 'cos it really hasn't got a chance to come out, that's what I think anyway 'cos you're swirling it that fast and it really can't come out. It's supposed to be something to do with gravity but I can't see how it can be." (F3, girl)

Others have it worked out to their own satisfaction. The following is a conversation between the interviewer (I) and three students together.[9]

I. "Would we still have gravity if the earth stopped rotating?"

All. "No."

P.3. "What might happen is logical 'cos - um - well, you know, if you go to some of these parks and that, and things are spinning, and if you stay, if you get these special spinning things - if you're tended to be pushed outwards, but if you're on the inside, you know, sometimes if you get really close to the inside, you're tended to be pulled in to the middle."

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[9] This was a unique interview as it was not with an individual student. These students are not included in the totals provided for the number of students interviewed in this investigation.

I. "Hmm, now on the earth though, are we not on the outside? I would've thought that as we're spinning we'd be tended to be flung away from the earth?"

P.3. "Yeah, yeah, but we're close to the centre, sort of thing."

I. "You might be, but I'm not! I'm on the outside, believe me!"

P.3. "Yeah, yeah, I mean, you know, I'm talking about the whole earth mass as being the centre sort of thing."

P.2. "It's going around so fast it's just keeping us here."

P.1. "The gravity would be strong because of the spinning motion."

P.2. "It's just a kind of force field holding us down, sort of thing."

GRAVITY AND ACROSS-CONCEPTS ASPECTS OF CHILDREN'S VIEWS

In other papers in this series (e.g. FORCE, No. 16; FRICTION, No. 19) we have documented some general aspects of students' views. This series of interviews on GRAVITY provided an opportunity to add further examples to this list.

(a) Everyday language

Gravity, like friction, is not a commonly used word in the everyday language of Form 1 and Form 2 pupils. No student when asked "What is gravity? Can you tell me about it?" referred to the non-scientific meaning, i.e. seriousness. As mentioned earlier 9 students (1 x F1, 2 x F2, 3 x F3, 3 x F4) could initially give no explicit meaning for the word, and of these (1 x F1, 1 x F2, 2 x F3, 2 x F4) had very little idea at all. The Form 1 student had been told about gravity the year before but the only thing that could really be remembered was an episode in which she had guessed an answer in class and got it correct (see Appendix 2). Other students had a very vague idea which appeared to be associated with movement but we were really unable to evoke any clear meaning.

We have a clear impression that gravity is a word not found in the everyday language of children. As two of the Form 4 girls, who really had no idea independently stated:

"Gravity is something to do with science."

(b) Self-centred and human-centred viewpoints

There were fewer examples of self-centred or human-centred viewpoints in this set of interviews than in any other of our investigations. This may well relate to their general unfamiliarity with the word gravity. It is not surprising that on occasions pupils tended to focus on the human aspects of the diagrams being considered rather than on the unobservable gravity. To a third form girl the bucket drops because "she let the rope go", to a fourth form boy it drops "'cos she won't be holding it". Such views are quite valid and merely show a different focus than the interviewer might have intended. Other students however (1 x F1, 2 x F3, 2 x F4) tended to more specifically attribute the cause of motion to the person. For one third form girl a boy on a slide comes down, not because of the effects of gravity but "'cos he's forcing himself"; a boy trips on stairs and fall because "his foot" makes him fall; the bucket (Card 6) moves because "It's all her force". Humans even substitute for gravity:

> "(What makes the bucket go up and what makes the bucket go down?) Oh, she's sort of like a gravity to the bucket 'cos she's pulling it up, and she's making it go up by pulling the rope and then if she just lets it go loose, it goes back down. (And what makes it go back down?) Oh, really she does, 'cos it's connected onto the rope ... so if she lets the rope go up a bit, a bit more ... the bucket will be down more." (F1, girl)

And gravity is important!

> "I think it's fairly important because if it wasn't around us, we wouldn't be able to live very happily because it would be a bit unfair in sports. Say, if you go for a big six and it goes for miles away and you can't find the ball and (with each) single bowl you've got to get a new ball ... it keeps the cost of things down, I suppose, 'cos you don't need to wear heavy lead boots and things like that around!" (F4, boy)

(c) Attributing animal or human characteristics to non-living things

Few examples of animistic views were found in this set of interviews. Two examples from fifth form students are worth quoting however,

> "(Card No. 3, See-saw) Gravity's deciding which way to go." (F5, girl)

"(Card No. 8. Rocket) Gravity wants to keep it down." (F5, boy)

Some vestiges of animistic ideas might be behind the following response:

"The moon doesn't need a lot of gravity ... it only needs gravity to hold it in the circuit of the earth. (Why does the earth itself need more gravity than the moon?) It's bigger and it's got an atmosphere to hold down. It's got the moon to hold in." (F4, boy)

(d) Reified views

Very few examples were documented where students attributed a reality to gravity which was unjustified. Two students only can be quoted. A Form 1 girl, had a very definite concept which, in spite of being strongly challenged by the interviewer, remained coherent and consistent. To her, gravity was able to 'flow' through objects, imbuing them with a magnetic-like attractive force. "... it's (gravity) not above the ground, it's in the ground." When asked if birds are affected by gravity, she explained how birds stay on power-lines, "The power poles are on the ground and it (the gravity) goes up through the power poles and in the lines, so it just keeps the bird there." A little later, in response to a query asking if passengers in an aeroplane experienced the effects of gravity, she answered "yes" and explained how the gravity gets into the aeroplane:

"They (aircrew) close the door before they take the ladder off, 'cos the ladder has got the gravity in it, going up to the plane, and then they close the door, and then they take the ladder away. (It traps it inside?) Hmm." (F1, girl)

Another student expressed a similar opinion. Her response to the card showing a person walking up stairs (No. 4) was:

"Yes, when you put your feet on the steps, it (gravity) holds (the feet) down. (Mmm, what say he didn't have his feet on the steps? For example, if you held onto a bar and you pulled yourself up and your feet were off the ground. Does that change the gravity at all?) Ah - no, 'cos your hands are holding on. (So where's the gravity then?) On your hands." (F2, girl)

DISCUSSION

While it is clear that the majority of students do view gravity as a "holding down" push or pull, there are a number of ways in which students' views about gravity differ from those of scientists. Our work suggests that for many students

* weight and the force of gravity are considered to be different.
* reaction forces and buoyancy forces are aspects of the force of gravity.
* gravity varies with height in a quite different way to the scientific view.
* gravity is the result of the presence of air pushing down.
* there is no gravity in space, including on the moon.
* gravity is caused by the earth spinning

The questions we might ask are these.

1. How many of these non-scientific views should we attempt to modify towards a more scientific viewpoint in Form 3 and Form 4, and how do we go about it?
2. How important is it to introduce ideas about gravitational forces to Form 1-4 students? Gravitational forces are abstract and no doubt difficult to understand from a scientific point of view. To whom, when, and for what purpose do we want to teach about gravity?
3. When we teach about gravitational forces in the senior school, how many of the scientific ideas about gravity (e.g. it is independent of air) do we unjustifiably assume students do know already? Much of our work about electrical fields is based on an anology with gravitational fields. What confusion is introduced if the understanding of some of the basic ideas about gravitational fields is invalid?

So many questions. As yet, so few answers.

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The Physicists' Perspective

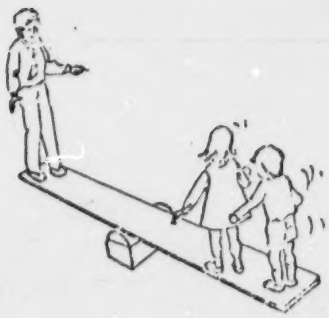
1.

There is a gravitational force on the spaceman, assuming he is near the earth or the moon. If the man is is orbit around the earth, the gravitational force keeps him in orbit.

2.

There is a gravitational force on the bird which is balanced out by the forces produced by the air moving over the wing.

3.



There are gravitational forces both on the man and the children. If the, were all the same distance from the pivot, the gravitational force on the man would equal the total gravitational force on the children, provided the see-saw is balanced. The upwards reaction forces provided by the plank, balance out the gravitational forces on the people.

4.

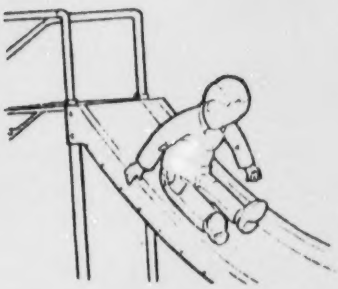
There is a gravitational force on the boy, which is balanced out by the upward reaction forces provided by the stairs.

5.

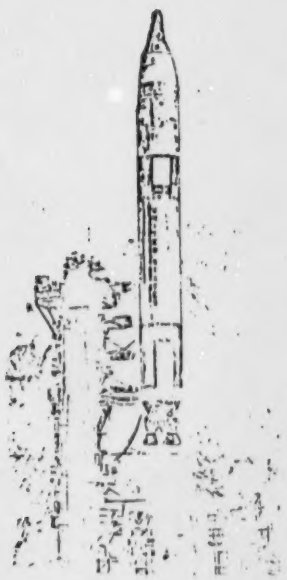
There is gravitational force on the swimmer largely balanced out by upthrust of the displaced water (buoyancy forces)

6.

There is a gravitational force on the bucket. If the bucket is stationary then the tension force in the rope is equal and opposite to the force of gravity.

7. 

There is a gravitional force on the child. This force will be the same for all positions of the child on the slide. The reaction forces are always at right angles to the slide surface.

8. 

There is a gravitational force on the rocket, and this force will still be present to some extent after the rocket goes well beyond the atmosphere.

APPENDIX 2

Irene, Form 1, really had no ideas about gravity, except that "it is everywhere".

K "How do you know gravity is everywhere?"

I "Um ... 'cos last year ... oh ... I said gravity was everywhere and I was right ... I don't know if it was right or wrong."

K "You studied this last year, did you?"

I "Hmm."

K "I see, this was in Standard 4?"

I "Hmm."

K "Ah, so what sort of things were you doing with gravity?"

I "Oh, we only talked a little bit about it and we've studied these rocks that Mr Mills had at his place."

K "Hmm. And how did the rocks tie in with gravity?"

I "I don't know."